Prophylactic use of the silver-acetate–coated graft in arterial occlusive disease: A retrospective, comparative study

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Objective: **Silver-coated vascular polyester prostheses were developed not only for the treatment of prosthetic graft infections, but also for use as prophylaxes. Although some studies describe the use of these prostheses in cases of infection, there are few data on their prophylactic use. This study compares the performance of the InterGard Silver polyester graft (Intervascular, Datascope, Inc, La Ciotat, France) with that of standard prostheses in routine use.**

Methods: **This retrospective study included all patients who received alloplastic bypass for treatment of arterial occlusive disease at the University Hospital in Würzburg from January 1996 to December 2006. The courses of disease were analyzed by examining the medical records. Follow-up research documented long-term results.**

Results: **The cases of 913 patients were analyzed (430 silver grafts, 483 standard grafts). Indications for the operations were claudication (silver: 136, nonsilver: 212), rest pain (49/65), tissue loss (135/148), and acute occlusion (110/58). Prosthetic implantation was performed in the aorto-iliaco-femoral position (silver: 93, nonsilver: 146), in the femoro-distal position (309/304), and as multilevel reconstruction (28/33). With regard to perioperative complications, the two groups did not differ significantly. There were no silver release-related complications, such as colored exudation or wound staining. Mean follow-up time was 56.7 ± 1.6 (SEM) months. When corrected for redo procedures, stage of disease, and type of reconstruction, both materials performed equally well: 5-year patency for claudication: silver 91%, nonsilver 95%, femorodistal 47%/41%; 5-year patency for critical ischemia: aortofemoral 88%/93%, femorodistal 31%/35%; 5-year limb salvage (critical ischemia): aortofemoral: 78%/79%; femorodistal: 59%/67%. Graft infections (Szilagyi grade III) were detected in 59 patients (6.4%; silver: n = 32, 7.4% vs control: n = 27, 5.5%; *P* = .28) after an average of 321 ± 96 days. One infection occurred out of 93 aortofemoral operations with the silver prosthesis (1.1%) compared to 4.1% (6/146) in the control group (*P* = .17). For patients with femorodistal grafts, silver exhibited an infection rate of 9.4% compared to 5.9% (*P* = .11). In the multiple regression analysis, two factors influenced the rate of a graft infection significantly: wound healing impairment and revision after bypass implantation. Silver did not prevent a subsequent bypass infection in these cases (silver: 18.1% vs 12.5%, *P* = .27).**

Conclusion: **The silver-coated prosthesis did not differ from standard materials. Silver had no significant effect on the risk of graft infection. Our study showed good results with the silver prosthesis in the aorto-iliaco-femoral position, but in cases of femorodistal grafting, a reduction of prosthetic infections was not achieved. The silver grafts did not prevent subsequent infections in cases of tissue loss or postoperative local complications.** **(J Vasc Surg 2009;50:790-8.)**

The first silver-acetate–coated graft (InterGard Silver; Intervascular, Datascope, Inc, La Ciotat, France) was introduced to the market more than 9 years ago. According to the product description, it was "designed for routine use in vascular bypass procedures". In early 2006, another silver-coated device, the B. Braun Silver Graft, became available (B. Braun, Inc, Melsungen, Germany). Whereas the silver degrades from the InterGard conduit within 4 weeks*, the Braun graft has a slower release, lasting for more than a year.[1] Silver prostheses are more expensive than their uncoated counterpart: according to list prices published by the manufacturer (Intervascular), the silver-acetate–coated prosthesis costs 14-16% more than the uncoated implant.

Although the effectiveness of silver-coated grafts has been shown in-vitro, there is still controversy concerning in-vivo animal studies.[1-3] These studies, where the silver-acetate–coated polyester prostheses performed less well than rifampin-soaked grafts, have been criticized.[4,5] The InterGard Silver prostheses were sterilized in an autoclave before being implanted in animals. Such procedures, which are not allowed according to the manufacturer, may alter the coating; furthermore, the infection model chosen was said to be unrealistic, as the bacterial strain used was highly sensitive to rifampin and the strain itself could not be identified by reference number.[4,5]

Some authors have reported the successful treatment of infected grafts with in-situ reconstruction using silver grafts.[6,7] Despite the implementation of enhancements in surgical techniques (eg, the perioperative use of antibiotics

*According to the manufacturer, "the silver release profile is designed to be most active during the initial 24 hours postimplant, with continuous and substantial release for a 7-day period" Source: http://www.intervascular.com/eng/products/pdf/intergard_silver_brochure.pdf (cited April 2006).

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Table I. Characteristics of the study group (silver) and the control group (nonsilver)

Parameter	*Patient characteristics*	*All (n = 913)*	*Silver group (n = 430)*	*Control group (n = 483)*	P *value*
Basic data	Age	68.8 ± 9.8	69.5 ± 0.48	67.9 ± 0.51	.029
	Male-female ratio	2.3:1	1.6:1	2.9:1	.015
Indication	Claudication	348 (38.1%)	136 (31.6%)	212 (43.8%)	<.001
	Rest pain	114 (12.5%)	49 (11.4%)	65 (13.5%)	.368
	Tissue loss	283 (31.0%)	135 (31.4%)	148 (30.6%)	.830
	Acute occlusion	168 (18.4%)	110 (25.6%)	58 (12.0%)	<.001
Previous procedure on the vessel	Any procedure	298 (32.6%)	166 (38.6%)	132 (27.3%)	<.001
	Bypass in groin	134 (14.7%)	82 (19.1%)	52 (10.8%)	<.001
	PTA	112 (12.3%)	78 (18.1%)	34 (7.0%)	<.001
	TEA	54 (5.9%)	34 (7.9%)	20 (4.1%)	<.001

PTA, Percutaneous transluminal angioplasty; *TEA,* thrombendarterectomy.
Statistics: for nominal data, the χ^2 test was used, for numeric data, *t* test.

and antimicrobial incise drapes), the incidence of a severe infection (Szilagyi grade III) of an alloplastic vascular graft remains a major problem, and some studies report increasing incidence in recent years.[8]

Study objective. The aim of the study was to assess the short- and long-term performance of silver-acetate–coated polyester prostheses in comparison with nonsilver grafts. Complications, mortality, patency, limb salvage, and development of graft infection served as essential parameters.

MATERIALS AND METHODS

The study was done in the Department of Vascular and Endovascular Surgery at University Hospital in Würzburg, Germany. In a retrospective analysis, all patients that received alloplastic prosthesis in the aortofemoral or femorodistal position from January 1996 until December 2006 were identified by examining the documentation of the operating unit. The InterGard Silver graft was introduced to our unit in 1999. Aneurysms, prosthetic infections as diagnosis, and rarely-performed surgeries were excluded. During that time period, a Dacron graft was the material of choice for aortofemoral and Dacron graft or polytetrafluoroethylene (PTFE) for above-knee femorodistal bypasses. For below-knee reconstructions, the great saphenous vein was preferred. In absence of this vein, or to reduce operation time in emergency cases, or in old patients, a Dacron graft or PTFE was used.

The case files were retrieved, and the following data were collected: patient-dependent factors, pre-, intra-, and postoperative details, and further therapies. Wound healing disturbance was noted, if the incision wound did not heal properly (wound dehiscence). A lymphatic fistula was stated if a lymphocele developed or wound secretion was prolonged (>7 days). When the study was carried out in December 2007, a follow-up examination was scheduled. The patients were invited to undergo an exact examination. Graft patency was documented by palpable pulse and duplex ultrasound scan. If the patient refused to come to the hospital, a telephone interview was conducted, or the family doctor was questioned. For those patients for whom no actual information could be obtained, the status of the last examination was recorded ("lost to follow-up"). The study's main endpoint was development of graft infection (Szilagyi grade III – involvement of the arterial implant). Graft infection was usually suspected clinically and confirmed by computed tomography (CT) scan. Secondary endpoints were mortality, bypass patency, and limb salvage.

The data were collected using MicroSoft Excel (Redmond, Wash). Statistical evaluation was carried out using SPSS software for Windows v. 16 (SPSS Inc, Chicago, Ill). In addition to descriptive data analysis (mean, SE), other tests were performed. To compare nominal variables, the χ^2 test was employed. For metric data, such as age, the samples were analyzed by *t* test for independent samples (two samples) or analysis of variance (ANOVA) (>2 samples). Binary logistic regression analysis was used to estimate the importance of each factor. Patency, limb salvage, and survival data were demonstrated using the Kaplan-Meier method and the log-rank test. The level of significance was set at $\alpha = .05$.

RESULTS

Until December 2006, 430 patients received a silver graft for acute or chronic arterial occlusion of the lower limbs (study group). From 1996 until December 2006, 483 additional prostheses without silver were implanted in the aortofemoral and/or femorodistal position (control group). The majority of these grafts had been implanted before the year 2001 (n = 335, 69.4%).

Short-term results. The control group and the study group differed in several parameters (Table I). For the silver group, patients were older, and more females had surgery. Although the percentage of cases with chronic critical limb ischemia (rest pain and tissue loss/gangrene, Rutherford stages 4, 5, and 6) was comparable for the groups, significantly more patients with claudication had surgery in the control group. With acute occlusion (limb threatened, Rutherford stages 2a and 2b), more patients had surgery in the study group. Because of the retrospective character of the study, it was not possible to distinguish the different clinical grades 2a and 2b. Diabetes was found in 356 patients (39.0%), hypertension in 691 (75.7%), cardiac

Table II. Indications and bypass types for the 913 patients who received an alloplastic bypass

Indication/position of the graft	*All (n = 913)*	*Claudication (n = 348)*	*Rest pain (n = 114)*	*Tissue loss (n = 283)*	*Acute occlusion (n = 168)*
Aortobifemoral (n = 186)					
silver	53	24	7	13	9
nonsilver	133	80	11	32	10
Aorto-iliaco-femoral[1] (n = 53)					
silver	40	18	7	3	12
nonsilver	13	7	0	1	5
Femoropopliteal (AK) (n = 249)					
silver	119	64	8	35	12
nonsilver	130	77	4	34	15
Femoropopliteal (BK) (n = 105)					
silver	48	9	8	23	8
nonsilver	57	17	10	28	2
Femorocrural+pedal (n = 259)					
silver	142	14	16	52	60
nonsilver	117	17	34	46	20
Multilevel[2] (n = 61)					
silver	28	7	3	9	9
nonsilver	33	14	6	7	6
Sum					
silver	430	136	49	135	110
nonsilver	483	212	65	148	58

AK, Above-knee; *BK,* below-knee.
Depicted are the absolute numbers for the study group (silver) and the control group (nonsilver).
[1]Ipsilateral or cross-over; [2]aorto-iliaco-femoral and femorodistal.

Table III. Intraoperative complications and relevant local postoperative complications

Complication	*All (n = 913)*	*Silver group (n = 430)*	*Control group (n = 483)*	P *value*
Intraoperative complications				
Thrombotic occlusion	76 (8.3%)	33 (7.7%)	43 (8.9%)	.582
Injury of intestine, ureter, or bladder	4 (0.5%)	3 (0,6%)	1 (0,2%)	NC
Cardiac	4 (0.5%)	2 (0,5%)	2 (0,5%)	NC
Local postoperative complications				
Subcutaneous infection/hematoma	39 (4.2%)	16 (3.7%)	23 (4.8%)	.540
Lymphatic fistula	129 (14.1%)	57 (13.3%)	72 (14.9%)	.535
Wound healing disturbance	148 (16.2%)	72 (16.7%)	76 (15.7%)	.503
Revision due to local complications	133 (14.3%)	59 (13.7%)	74 (15.2%)	.555

NC, Not calculated because of low number.
Statistics: for nominal data, the χ^2 test was used, for numeric data, *t* test.

disease in 420 (46.0%), and endstage renal disease (dialysis) in 75 (8.2%). Fifty-four percent (498) were smokers. The vessels of 298 patients (32.6%) had been treated before, up to 7 times (silver: 166, 38.7%; control: 132, 27.3%; $P <$ .001; Table I). The groin had been used for a previous bypass placement in 134 cases (silver: 82, 19.1%; control: 52, 10.8%; $P < .001$). An actual occlusion of one of these bypasses led to implantation of a prosthesis in 93 cases (silver: 57, 11.8%; control: 36, 7.4%; $P < .001$).

The surgeries performed are listed in Table II. Silver prostheses were implanted predominantly in patients with limb-threatening ischemia, particularly in the femorocrural position. Of the 259 femorocrural reconstructions, 196 (76%) received a vein cuff for the distal anastomosis (silver: 131/142, 92%; control: 65/117, 55.5%; $P < .001$).

The rate of intraoperative complications did not differ significantly between the two groups. Thrombotic occlusions were found in 7.7% of the silver prostheses and 8.9% of the control group (Table III).

During the first 30 days after the operation, severe pulmonary problems (mainly pneumonia) were the most common of the systemic complications (n = 39, 4.3%). Renal complications (temporary renal failure) occurred in 35 patients (3.8%). Stroke (n = 4, 0.6%) and clinically apparent heart attack (n = 10, 1.1%) were seldom experienced. A heparin-induced thrombopenia type II was noticed in 4 patients (0.4%).

Regarding local complications, lymphatic fistulas occurred in noticeable numbers (n = 129, 14.1%, comparable for both groups, Table III). Wound-healing disturbances/infections were noticed in 148 (16.2%) and 39 (4.2%) patients, respectively, again without noteworthy differences between groups. A total of 133 operations were performed as a result of local complications during the first hospital stay (14.3%). Silver release-related complications appearing as colored secretion or wound staining did not occur.

A total of 49 patients died during their hospital stay (5.4%), 3 of them because of an early bypass infection (2 in the silver group). For patients with intermittent claudication (peripheral arterial occlusive disease [PAOD] Rutherford stage 3), none of the patients in the silver group died, compared with 3 in the control group (1.4%). Attributed to the aortic position of proximal anastomosis, mortality was 9.9% in the silver group, compared with 5.5% in the control group. For the patients with proximal anastomosis in the groin, mortality was lower for the silver group (3.6% vs 4.9%). None of these differences were statistically significant.

Long-term results. The mean follow-up time was 56.7 ± 1.6 (SE) months. Eighty-three patients refused to meet in person, so the information was obtained by telephone in these cases. A total of 102 patients were lost to follow-up (11%) after an average time of 28.5 ± 2.3 months, and 301 (33%) patients died after dismissal. Most deaths were related to cardiac disease (152 patients, 51,8%), followed by tumors (57, 18.9%), and sepsis (11, 3.6%) because of a subsequent bypass infection (see below). In the remaining cases, death was due to renal failure, liver failure, ileus, or stroke, or could not be determined. Survival rate differed significantly depending on the indications ($P < .001$), with the lowest 5-year survival rate among patients with gangrene (43.6% ± 3.8) and the highest among those with intermittent claudication (77.9% ± 2.8). Five-year survival for patients with rest pain (68.6% ± 4.9) was slightly higher than that for those with acute occlusion (63.4% ± 4.7).

A total of 359 bypass occlusions occurred (silver group: 191; control group: 168; mean time until occlusion: 364 ± 34.7 days). In most patients, the reason for thrombosis was bad outflow. Fig 1, *a,* shows overall primary patency rates. Claudication exhibited significantly better patency (5-year patency: 70.1% ± 3.1), while rest pain (45.0% ± 5.1), tissue loss (48.7% ± 4.0), and acute occlusion (42.4% ± 5.0) had comparable results (Fig 1, *a*). Comparing all prostheses together, we found that the control group exhibited a better patency than the silver group (5-year patency: 53.8% ± 3.9 vs 36.9% ± 4.2, respectively). To exclude bias, we calculated the 5-year patency or limb salvage for subgroups. There were more redo procedures (in particular for bypass occlusion) in the silver group, so we confined the calculation to the cases in which no bypass had been implanted before. As shown in Fig 2, *a*, patency in claudication was still better for the control group (5-year patency: 81% ± 3.5 vs 57% ± 5.7). This may be attributed to the fact that there were substantially more aorto-(bi-)femoral procedures in the nonsilver group. Fig 2, *b*, depicts patency for those cases with aortofemoral prostheses for claudication, with both groups exhibiting comparable patency (control: 95% ± 2.7 vs silver: 91% ± 6, not significant). For cases with critical ischemia, the patency for the aortofemoral bypasses was lower (control: 93% ± 2.8 vs silver 88% ± 7.1, not significant). The femorodistal reconstructions demonstrated comparable results for both groups in the patients with claudication (silver: 47% ± 6.8 vs control 41% ± 9.9, not significant) and in the cases with chronic critical ischemia (Fig 2, *c*; silver: 31% ± 4.7 vs control: 35% ± 4.5, not significant).

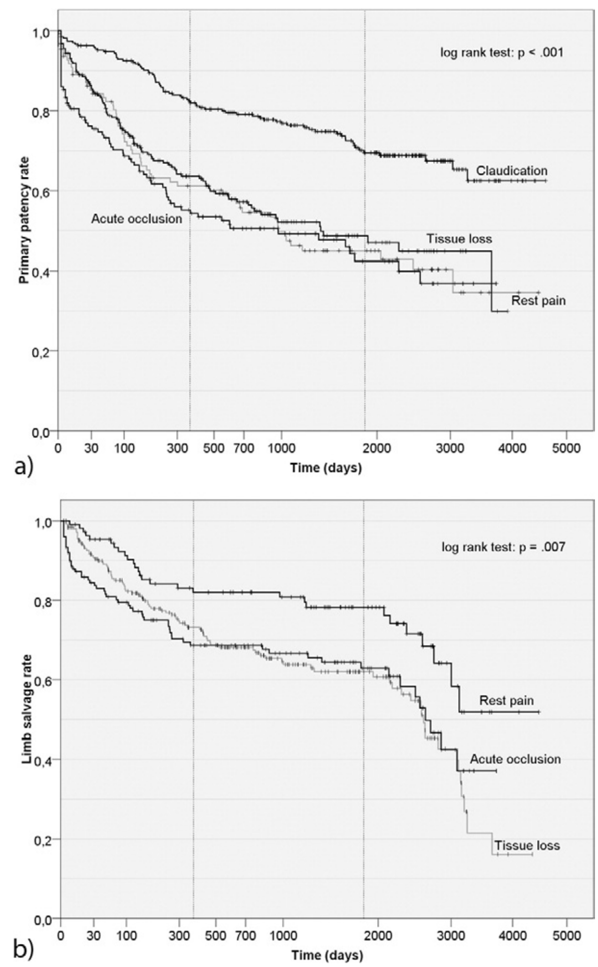

Fig 1. Overall primary patency and limb salvage rates for the different indications (Kaplan-Meier). **a,** The patency rate for claudication is significantly better, while the curves for rest pain, tissue loss, and acute occlusion do not differ. **b,** In contrast, rest pain has a significantly better limb salvage rate compared to tissue loss and acute occlusion. *Vertical dotted lines*: 1 and 5 years.

By definition, limb salvage must be calculated for patients suffering from critical ischemia (n = 565). In this group, 112 legs had to be amputated, 39 of them within 30 days after graft implantation. In contrast to the patency rate, the limb salvage rate differed between the indications of rest pain and tissue loss/acute occlusion significantly (Fig 1, *b*). The overall 5-year limb salvage rate for patients with limb-threatening limb ischemia was significantly lower for the silver group (58.2% ± 3.7 vs 74.6% ± 3.2; $P = .04$, Fig 3, *a*). We examined the rates of different diagnoses and types of surgeries. Again, as shown for patency, the silver and control groups did not differ significantly in the subgroup analysis. As can be seen in Fig 3, limb salvage rates for those cases with aortofemoral (silver: 78% ± 7.9 vs control 79% ± 6.3; Fig 3, *b*) and femorodistal (Fig 3, *c*) are

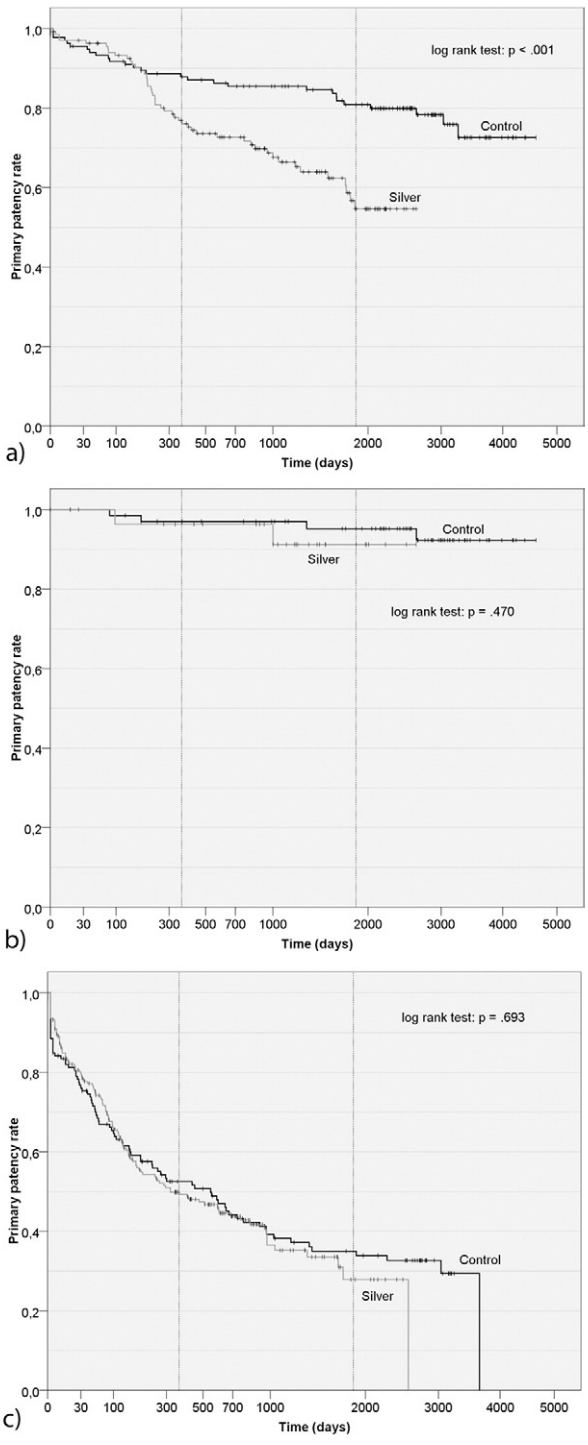

Fig 2. Primary patency rates (Kaplan-Meier). **a,** Patency for the silver and nonsilver groups in patients with claudication (all operations). The control group seems superior. **b,** Subgroup analysis: patency rate for aorto-(bi-)femoral prostheses in claudicants, previous procedures on the vessel excluded. There is no difference between the groups. **c,** In femorodistal prosthesis implanted critical limb ischemia, the patency rates are similar. Statistic: log-rank test. *Vertical dotted lines*: 1 and 5 years.

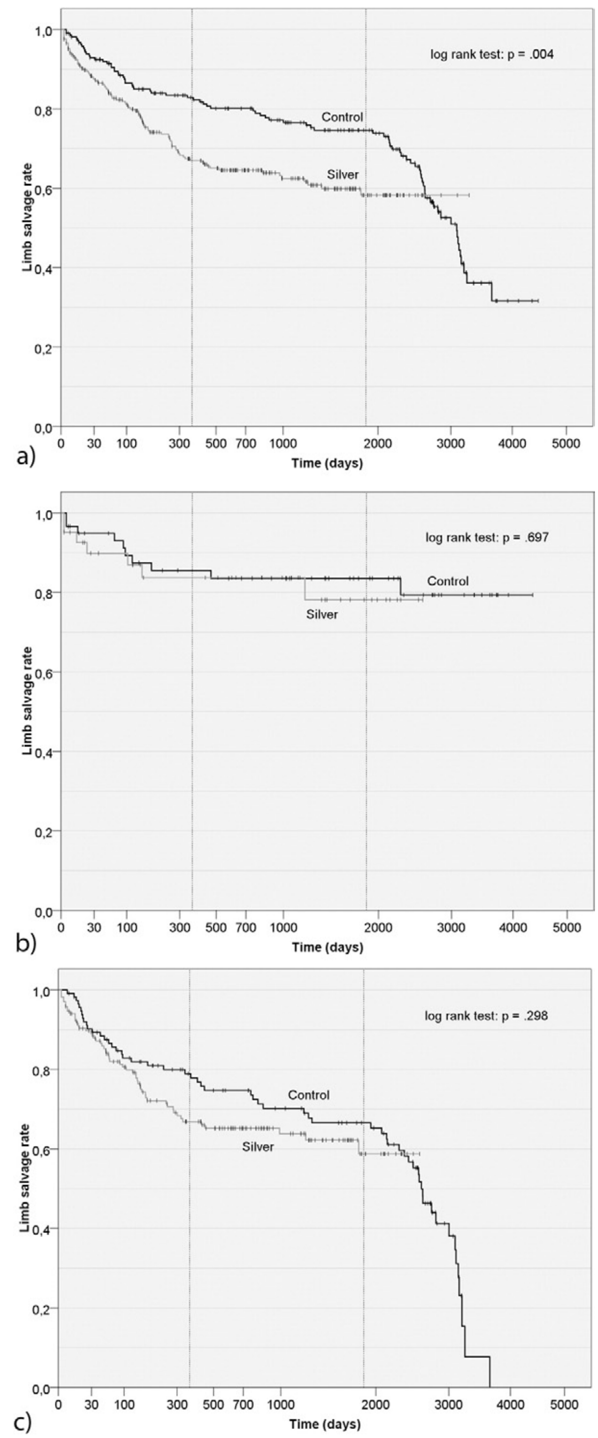

Fig 3. Limb salvage rates for patients with limb at risk (Kaplan-Meier). **a,** Overall performance. Again, the results for the silver group were inferior to the nonsilver group. **b,** Subgroup analysis: aorto-(bi-)femoral prostheses; there is no difference between the groups. **c,** Femorocrural prostheses (without redo procedures) did not show a significant difference. Statistic: log-rank test. *Dotted lines*: 1 and 5 years.

Table IV. Subsequent bypass infections for the different indications and bypass types of the 913 patients who received an alloplastic bypass

Indication/position of the graft	*All (n = 913)*	*Claudication (n = 348)*	*Rest pain (n = 114)*	*Tissue loss (n = 283)*	*Acute occlusion (n = 168)*	P *value*
Aortobifemoral (n = 186)						.541
silver	1 (1.9%)	0	0	1 (7.7%)	0	
nonsilver	5 (3.8%)	2 (2.5%)	0	3 (9.4%)	0	
Aorto-iliaco-femoral[1] (n = 53)						.382
silver	0	0	0	0	0	
nonsilver	1 (7.7%)	1 (14.3%)	0	0	0	
Femoropopliteal (AK) (n = 249)						.434
silver	7 (5.9%)	0	0	6 (17.1%)	1 (8.3%)	
nonsilver	6 (4.6%)	2 (2.6%)	0	2 (5.9%)	2 (13.3%)	
Femoropopliteal (BK) (n = 105)						.177
silver	8 (16.7%)	1 (11.1%)	2 (25%)	4 (17.4%)	1 (12.5%)	
nonsilver	5 (8.8%)	1 (5.9%)	2 (20%)	2 (7.1%)	0	
Femorocrural+pedal (n = 259)						.182
silver	14 (9.9%)	3 (21.4%)	1 (6.2%)	3 (5.8%)	7 (11.7%)	
nonsilver	7 (6.0%)	1 (5.9%)	4 (11.8%)	2 (4.3%)	0	
Multilevel[2] (n = 61)						.579
silver	2 (7.1%)	1 (14.3%)	0	1 (11.1%)	0	
nonsilver	3 (9.1%)	2 (14.3%)	0	1 (14.3%)	0	
Sum						.158
silver	32/430 (7.4%)	5/136 (3.7%)	3/49 (6.1%)	15/135 (11%)	9/110 (7.6%)	
nonsilver	27/483 (5.6%)	9/212 (4.2%)	6/65 (9.2%)	10/148 (6.8%)	2/58 (3.4%)	

AK, Above knee; *BK,* below knee.
Depicted are the absolute numbers and percentages for the study group (silver) and the control group (nonsilver). Statistic: χ^2 test.
[1]Ipsilateral or cross-over; [2]aorto-iliaco-femoral and femorodistal.

comparable (silver: 59% ± 5.3 vs control 67% ± 4.8, Fig 3, *c*). This alleged discrepancy between overall and detailed limb salvage can be explained by the fact that there were considerably more femorodistal procedures in the silver group (like stage migration or "Will Rogers Phenomenon" in cancer statistics).

A graft infection (Szilagyi grade III) was detected in 59 patients (6.4%), without statistical difference between the groups (silver: n = 32, 7.4% vs control: n = 27, 5.5%; P = .28). Of these 59 patients, 14 died in consequence of that infection (mortality 23.7%; silver: n = 9, 28.1%; vs control: n = 5, 18.5%; P = .39). Six patients died due to other reasons (3 of cardiac disease, 2 of tumors, and 1 of stroke) and 39 patients were alive without signs of infection when the follow-up study was conducted. The mean time until the graft infection became evident was 321 ± 96 days. A total of 18 infections (6 silver, 12 control) occurred during the first 30 days. We conducted a univariate ANOVA to determine which parameters influenced the development of bypass infection. No influence was seen by gender, age, acute operation, hyperlipidemia, diabetes, high blood pressure, smoking, adipositas, renal insufficiency, dialysis, cardiac disease, stroke, liver disease, pulmonary disease, number of risk factors, preceding percutaneous transluminal angioplasty (PTA), number of preceding procedures, preceding thrombendarterectomy, alloplastic material (PTFE/Dacron graft, silver), time of operation, anastomotic technique, lymphatic fistula, or postoperative pulmonary/renal/cardiac failure. Statistically relevant factors were the following:

1. Indication (claudication vs critical limb ischemia) (P = .019);
2. Type of bypass (aortic/iliac vs femoral) (P = .037);
3. Existing bypass in the groin (P = .042);
4. Wound healing disturbance ($P < .001$);
5. Postoperative local subcutaneous infection or bleeding ($P < .001$);
6. Postoperative revision (local) (P = .002).

Factors 1 & 2. Indication and type of bypass: analysis of the infection rate for all grafts related to indication showed that claudication had significantly fewer infections than the other indications (P = .012). The two groups did not differ significantly with regard to the indications or type of bypass reconstruction (Table IV). One infection occurred out of 93 aortofemoral operations with the silver prosthesis (1.1%) compared to 4.1% (6/146) in the control group (P = .17). For patients with femorodistal grafts, silver exhibited an infection rate of 9.4% compared to 5.9% (P = .11).

Factor 3. Existing bypass in the groin: the reason for the use of silver might be the redo operation in the groin. For patients who had undergone a previous procedure (PTA, thrombendarterectomy [TEA], or bypass), the infection rate was higher for the silver group than for the control group (Fig 4, *a, b*), statistically significant for previous bypass implantation.

Factors 4, 5, & 6. Local complications: another reason for the implantation of silver might be the prevention of infection in case of a local complication (prophylaxis). In our study, subsequent infections after postoperative local complications like wound healing disturbance were not reduced by the silver graft (Fig 4).

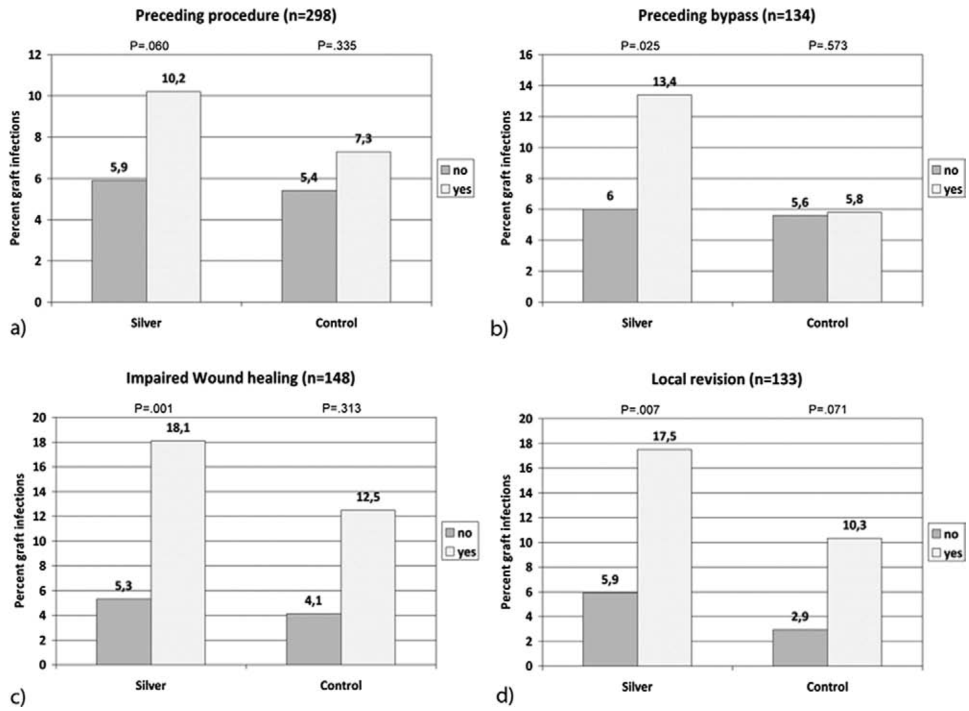

Fig 4. Infection rates for different local conditions. **a,** Preceding procedure (angioplasty, thrombendarterectomy, or bypass in the groin). **b,** Existing bypass in the groin. **c,** Impaired wound healing. **d,** Revision for local complication. In all groups, silver did not prevent an infection when compared to the standard graft. Comparing the silver group with the control group in **a**-**d**, the differences were not statistically significant. Statistic: χ^2 test.

In the multiple logistic regression analysis, two factors remained significant for development of a graft infection: wound healing disturbance and local revision. Therefore, the local complication remained the most important factor for developing a following graft infection. Silver did not reduce the rate of infections in these cases (Fig 4, *c, d*; silver: 18.1% vs nonsilver 12.5%; $P = .27$).

DISCUSSION

Although silver-coated prostheses have been marketed for routine use to prevent graft infection, only one study has been published so far describing the "daily" use of InterGard Silver grafts.[9] This study was limited to their use in the aortofemoral position and did not compare results with a control group. The results presented here are the first describing the application of silver prostheses in the femorodistal position and comparing them with standard alloplastic grafts.

The two groups differed in basic parameters, which may be attributed to the fact that the control group represented a longer period of time with the grafts, as many nonsilver grafts had been implanted before the year 2001. Patients in the silver group were older and included a higher percentage of females, which may be explained by demographic changes in recent years.[10] Another sign of the times is reflected in the lower number of patients in the "newer" study group operated on in the stage of claudication, especially for implantation of aortobifemoral prostheses. On the other hand, an increasing incidence of arterial occlusive disease is reflected in the fact of more previous procedures in the silver group, bypass implantations in particular.

Our study reviewed all types of standard bypasses implanted for acute or chronic arterial occlusive disease. In regard to intra- or postoperative complications, we saw no statistically relevant differences between the two groups. We did not note more typical intraoperative complications like bypass occlusions or bleeding that could be attributed to the special coating of the silver grafts. Staining of the wound or wound secretion did not occur, although it is known that silver ions released from devices may precipitate as silver sulfide.[11] These findings are in accordance with the results of the study previously mentioned.[9] The number of lymphatic fistulas and wound healing disturbances seem high in both groups. This may be explained by the relatively broad definition summarizing lymphoceles and prolonged wound secretion into lymphatic fistulas. A comparable incidence of lymphatic fistula has been noted for aortofemoral reconstructions in the literature (8.1%).[12] Another study described reducing 19% lymphatic complications to 10% by using fibrin glue.[13]

Although mortality with intermittent claudication was low (0.8%, none of the patients in the silver group), the rate for all patients was 5.4%. This rate seems quite high, but authors who studied comparable patients reported similar mortality rates of between 5.1% and 12%.[14-17] We did not see any significant differences between the silver and the nonsilver group in our study.

Looking at overall patency, the silver group did not perform and the nonsilver group. After correction for redo procedures, indication, and bypass position, the patency rates for the two groups were comparable. The primary patency rates for the aortofemoral reconstructions in our study were excellent. In contrast, patency rates for femorodistal operations were much lower. Similar results can be found in the literature with unfavorable results for femorocrural and femoropedal alloplastic bypasses.[16,18,19]

The literature provides evidence that limb loss is frequently the consequence in cases of bypass occlusion;[20,21] therefore, patency and limb salvage rates should be comparable. The limb salvage rate in our study was much better than the patency rate, which means that the extremity can be obtained even though the bypass is occluded. Currently the concept is accepted that, in many cases, bypass function is needed only to achieve wound healing. An occlusion after wound healing may be irrelevant.

The results of the aorto-iliaco-femoral grafts for critical limb ischemia were acceptable, with an overall limb salvage rate of 79% after 5 years. Our results are comparable with other publications describing limb salvage for aortofemoral grafting for limb-threatening ischemia of 80-84%.[22,23] For femorodistal reconstructions, including femorocrural anastomoses, the limb salvage rate is also comparable to other studies reporting about 55-68% after 3 to 5 years.[24-26]

To prevent a graft infection, different procedures are used in vascular surgery. Regarding the materials used, grafts soaked with antibiotics have been employed with some success in the last 15 years. Silver-coated prostheses have been efficient in-vitro;[1,27,28] however, in-vivo experiments have produced controversial data.[2-5] According to the manufacturer, under clinical conditions the concentration of silver is reduced to 25% after 20 days; therefore, an effective silver dose is available for only 2-4 weeks. This should protect the bypass in case of previous groin surgery or local complications such as wound healing impairment or lymphatic fistula. After 4 weeks, the silver concentration is so low that the InterGard Silver prosthesis should be considered the same as any other polyester prosthesis.[5] Of the 59 infections noted in our study, only a minority took place in the first 30 days after implantation. The mean time until infection occurred was 321 days. According to the literature, the majority (50%-65%) of all prosthetic infections will develop during the early postoperative interval.[29-31] As both groups developed graft infections quite late, this discrepancy with the literature cannot be explained by the release of silver ions from the InterGard Silver graft in the first 4 weeks.

Looking more closely at the details of graft infections, one can see striking differences in the incidences. For claudication and rest pain, the silver group performed better than the control group. For aortofemoral procedures (all indications), there was only one infection (1.1%), compared with 4.1% in the control group. These incidences can be found in the literature; referring to aorto-iliaco-femoral reconstructions, the incidence of prosthetic infections is quite low, from 0.7% to 4.0% (Ricco et al[9]).

In contrast, for femorodistal prostheses implanted for tissue loss and acute occlusion, the silver grafts had more infections. In a recently published retrospective study, the incidence of bypass infection was as high as 11%, indicating an increase in recent years.[8] Tissue loss has been described as a risk factor for graft infection. Some groups have described more graft infections in patients with peripheral ulcer;[29,32] additionally, in a recently published study, Nguyen et al[33] noticed that patients with tissue loss were prone to more complications and infections.

In our univariate analysis, "typical" risk factors (previous procedures or local complications) were correlated with development of a graft infection. For these situations, the silver acetate prosthesis did not reduce the infection rate in our study (Fig 3). This is also valid for the two factors confirmed in the multiple regression analysis: wound healing disturbance and local revision. Although there are no data in the literature describing a correlation between local revision and subsequent graft infection, other authors report a high number of infections in cases of compromised wound healing. In an older study, Jamieson et al[34] found graft infections in 2.0% of patients without wound-healing disturbances, but in 18.2% of the other group. In more recent studies, wound infection and wound complications have been shown to be independent factors in graft infection.[35]

Therefore, in our setting, the implantation of a silver-acetate–coated polyester prosthesis did not protect against subsequent graft infection in those patients with femorodistal bypass for PAOD stage 5 or 6, or those patients with wound-healing problems or previous surgery.

Limitations of the study. As this is a retrospective study, there may be a relevant error in the collection of basic data from patients. Patients lost to follow-up amounted to 11% of the total. We do not know whether these patients developed a graft infection and/or bypass occlusion. The groups were not equal in terms of basic data and kinds of surgeries. We tried to reduce that bias by analyzing subgroups.

CONCLUSIONS

The use of the InterGard Silver prosthesis is safe, and the incidence of complications is comparable to that with standard prostheses. Special side effects did not occur. With regard to the standard performance parameters (patency and limb salvage), these prostheses were comparable to other materials. Looking at the development of consecutive graft infections, we achieved good results in aortofemoral reconstructions for every indication (including tissue loss), which may suggest the effectiveness of prophylactic use. As these results were not statistically significant, and the incidence of graft infections in this localization is very low anyway, it remains debatable if it is worth it to spend more for the silver-acetate–coated graft.

In cases where implanting femorodistal grafts was done for limb-threatening ischemia, or if a local complication occurred, we found no protection against graft infection. In our institution, the regimen has changed, and angioplasty is now preferred even for long segment occlusions if autologous material is not available.

AUTHOR CONTRIBUTIONS

Conception and design: AL
Analysis and interpretation: SR, AL, ED
Data collection: SR, AL, MF
Writing the article: AL, SR
Critical revision of the article: AL, ED, SR, MF
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